U.S.Department of Transportation
Federal Highway Administration

THE IMPORTANCE OF CONSTRUCTION CONTROL IN FOUNDATION ACCEPTANCE

Presented to Geo-Omaha 2023
02/10/2023

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THE STORY OF THE FHWA GEOTECHNICAL PROGRAM

- Formed in 1968 as a small group of experts placed in regional offices to address a number of slide related issues during interstate construction
  - Rock Slides
  - Degradable Shales
  - Failing Soil Embankments
- Focus during early years primarily on earthworks, and "expertise" among that group was variable
- Primary role –Technical assistance

THE STORY OF THE FHWA GEOTECHNICAL PROGRAM

- In the mid-1980's, the geotechnical group was moved from construction and maintenance division to the bridge division
- Geotechnical function evolved to support different highway design functions (e.g., structure foundations)
- Coincided with early significant research efforts, including:
  - Allowable stress on piles
  - Group behavior
- Static analysis really didn't exist in practice to date, and structural engineers performed most foundation design

DEVELOPMENT OF DYNAMIC PILE TESTING TECHNIQUES

Courtesy of Pile Dynamics

Courtesy of Radise International

Courtesy of Allnamics

DEVELOPMENT OF DYNAMIC PILE TESTING TECHNIQUES

- Led by Ohio DOT who was routinely running expensive load tests and wanted to develop a field computer to evaluate driving operations
- Started with closed-end pipe piles
- Expanded through cooperative effort sponsored by FHWA to include other pile types
- Led to Demonstration Project 17 on Pile Foundations and Testing
  - Precursor to our current guidance on Pile Foundations (GEC-12)
  - Basis for current AASHTO specifications

DEVELOPMENT OF DYNAMIC PILE TESTING TECHNIQUES

Measurement = Information

- Provides information on driving stresses, which allows for designers to know when a pile may be damaged during installation
- Energy measurements available, which allow users to better understand hammer efficiency
- Use of dynamic testing supplements load testing, or can be used exclusively to make foundation construction much more cost effective

Led to widespread use in public and private sector work worldwide

LOAD TESTING AND THE EMERGENCE OF LARGE DIAMETER FOUNDATION ELEMENTS

Courtesy of Pile Dynamics

LOAD TESTING AND THE EMERGENCE OF LARGE DIAMETER FOUNDATION ELEMENTS

- Over two decades, evolution of foundation construction has been significant
- Load magnitude and general demand per element has greatly increased
- Demand on geotechnical and structural materials has increased
- As a result, nominal dimensions have increased rapidly to accommodate more complex loading conditions
- This was made possible by advances in load testing and in construction equipment

REFERENCE MATERIALS AND TRAINING DEVELOPMENT

U.S. Department of Transportation
Federal Highway Administration

Publication No. FHWA NHI-06-088
December 2006

NHI Course No. 132012

SOILS AND FOUNDATIONS

Reference Manual – Volume I

National Highway Institute

U.S. Department of Transportation

Publication No. FHWA NHI-16-072
April 2017

NHI Course No. 132031

Geotechnical Engineering Circular No.5

Geotechnical Site Characterization

U.S. Department of Transportation
Federal Highway Administration

Publication No. FHWA-NHI-16-064
FHWA GEC 012
July 2016

NHI Courses No. 132021 and 132022

Design and Construction of Driven Pile Foundations – Comprehensive Design Examples

Developed following:
AASHTO LRFD Bridge Design Specifications, 7th Edition, 2014, with 2015 Interim. and *AASHTO LRFD Bridge Construction Specifications, 3rd Edition, 2010, with '11, '12, '13, '14, and '15 Interims.*

GUIDANCE MATERIALS AND TRAINING DEVELOPMENT

Introduced in 1983 with the Soils and Foundations Workshop manual, and developments address several issues for a small technical discipline at FHWA:

- Dealt with Frequently Asked Questions from DOTs
- Promoted best practices
- Allowed for deployment of new technology
- Documented the state of practice for design and construction procedures
- Allowed for the logical and safe expansion of technology
- Provides support for development and update of codes and specifications

FHWA GEOTECHNICAL PROGRAM

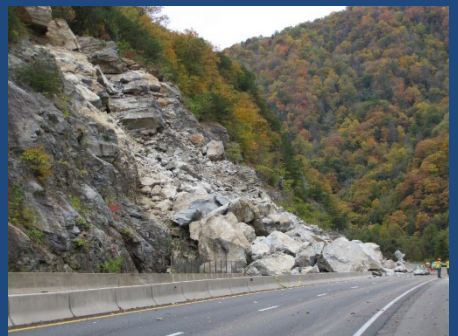
Objectives:

1. Update and maintain design and construction documents for geotechnical features
2. Provide State DOTs and transportation partners with tools and resources to more efficiently deliver programs
3. Identify and implement innovations and new technologies for more cost-effective highway construction

GEOTECHNICAL CHALLENGES IN TRANSPORTATION

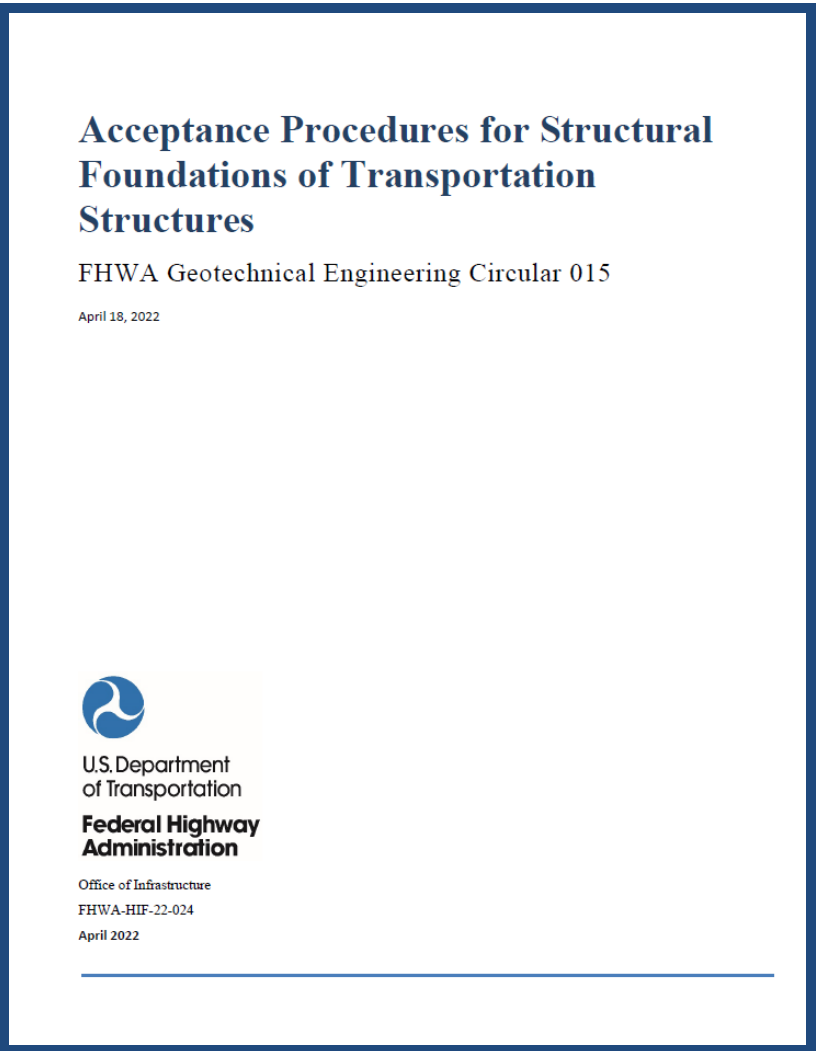
- Innovations in Geotechnical Design and Construction Methods
- Advanced Site Characterization
- Geotechnical Asset and Performance Management
- Geotechnics of Scour
- Geotechnical Aspects of Pavement






GEC-15: ACCEPTANCE PROCEDURES FOR DEEP FOUNDATIONS OF TRANSPORTATION STRUCTURES (FHWA-NHI-22-024)

- Published Spring, 2022
- Contract: WSP USA, Inc. with Dan Brown & Associates, L.P.
- Authors: Dan Brown, Ph.D., P.E.; Andrew Boeckmann, Ph.D., P.E.; John Turner, Ph.D., P.E.; and J. Erik Loehr, Ph.D., P.E.
- Intent of document is to provide a framework for facilitation of judicious and appropriate foundation acceptance decisions on
  - Driven Piles
  - Drilled Shafts
  - Micropiles
  - Continuous Flight Auger (CFA) Piles



FOUNDATION ACCEPTANCE

What Is It?

- A process that results in payment to the constructor for a deep foundation element.

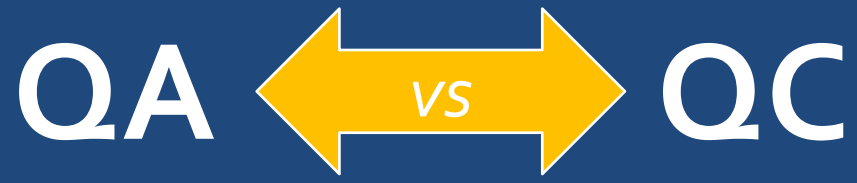
It Should Include

- Measurable and achievable acceptance criteria
- Documentation that the established acceptance criteria have been satisfied

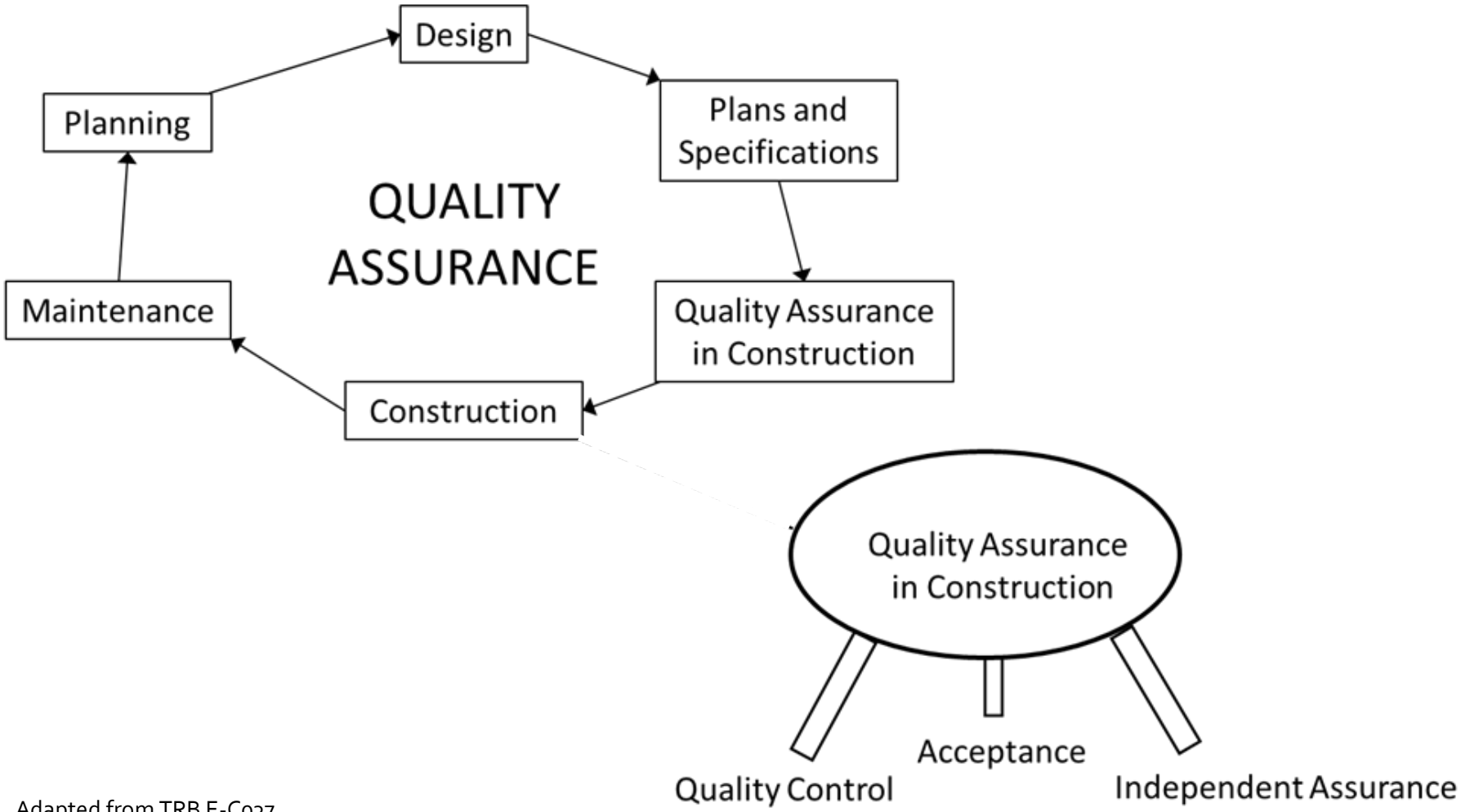
QUALITY ASSURANCE AND QUALITY CONTROL

- What is Quality Assurance?

- From TRB committee on Management of Quality Assurance:
  - *"all those planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service"*



QUALITY ASSURANCE SYSTEM ELEMENTS



Adapted from TRB E-C037

PROJECT DELIVERY INFLUENCES ON FOUNDATION ACCEPTANCE

- Contracting Structure
  - Change in responsibility and perspective
- Geotechnical Site Characterization
  - Identification of hazards and uncertainties
  - Potential for differing site conditions
- Design and Construction
  - What is constructible (considering uncertainties and risk)
  - Identification of potential risks during construction
  - Establishment acceptance criteria
  - Development of installation and QC plans
- EFFECTIVE COMMUNICATION!

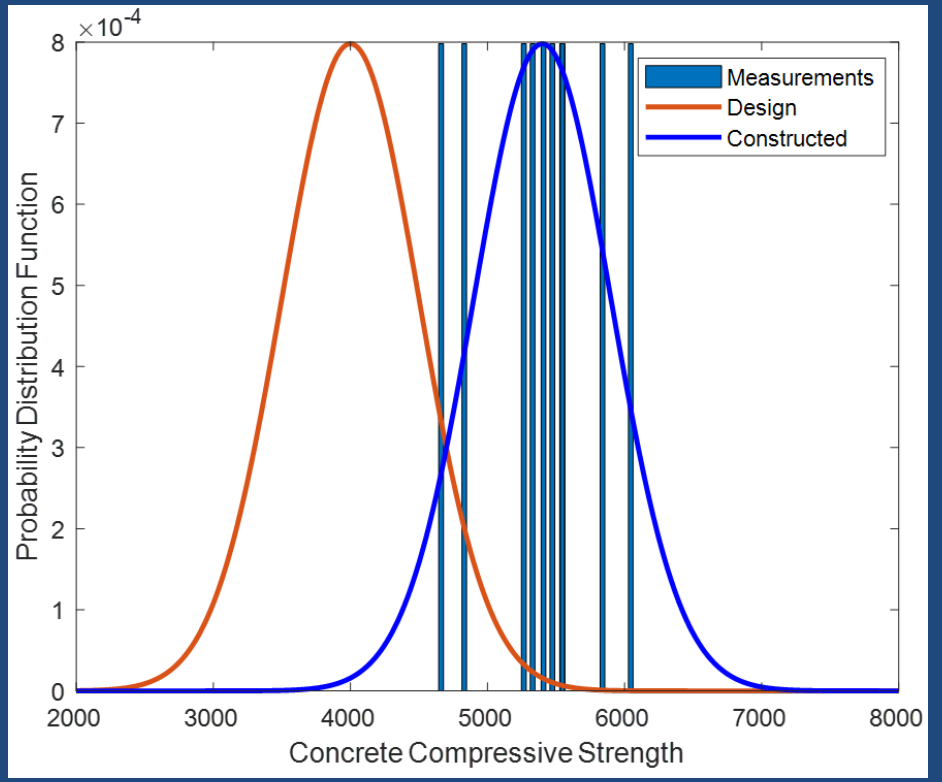
DESIGN VS. PERFORMANCE RELIABILITY

Design Reliability

- The reliability of an element during the design-phase
- Includes uncertainty in analytical models and material inputs

Performance Reliability

- The actual reliability of the constructed element
- Typically greater than design reliability because of
  - Conservative assumptions
  - QC practices
  - Observational method



ACCEPTANCE FRAMEWORK

- The framework is centered on documentation and communication of actual performance requirements for deep foundation elements in transportation applications
- Focus is on the four components of acceptance that should be part of information collection and considered in decision making:
  - Inspection Records
  - Construction Tolerance
  - Performance Verification
  - Element Integrity

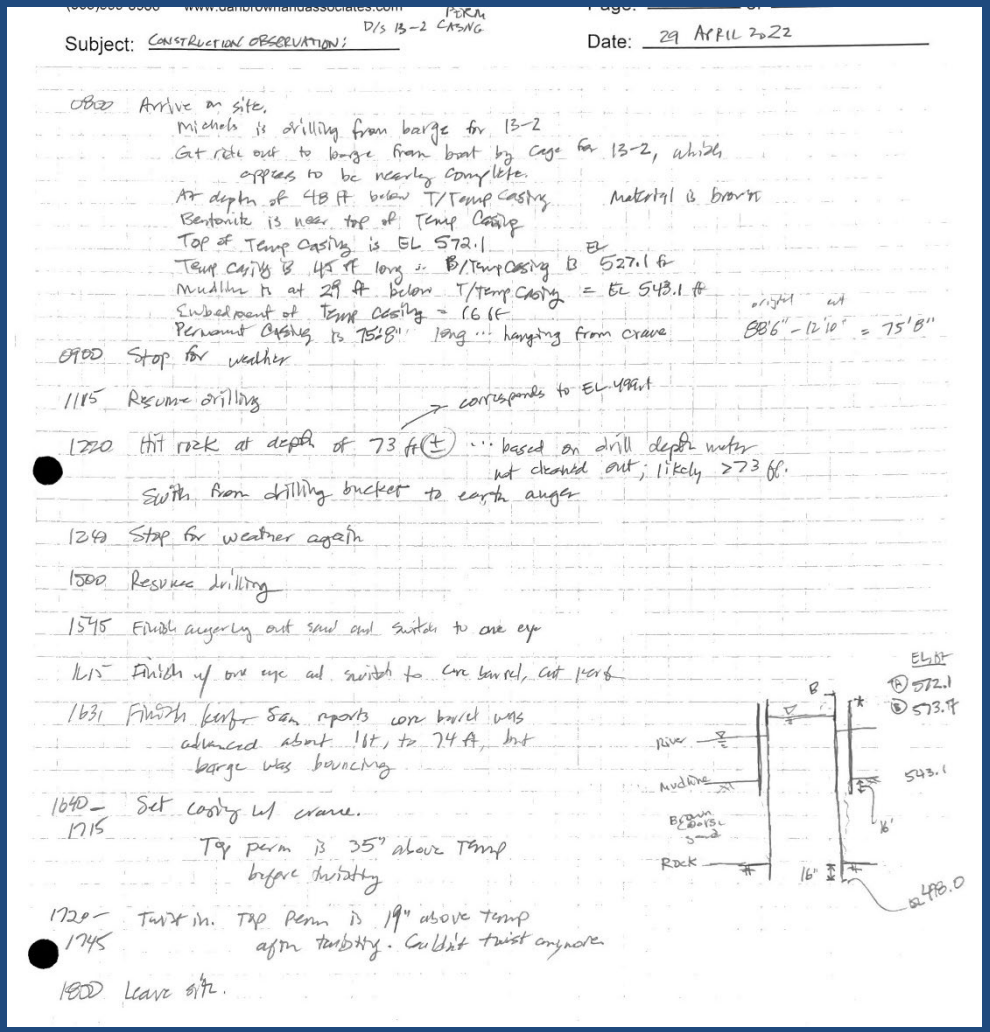
INSPECTION RECORDS AND CONSTRUCTION TOLERANCE

- Produces a permanent record of the foundation work and is a vital piece of construction control
- Documents observations of all work perform during various stages of foundation construction
- Verifies that construction conforms with plans, specifications, and the foundation installation plan
- Documents actual subsurface materials for changed or unforeseen conditions
- Includes measurements of components of the work during construction including as-built dimensions, location and materials

DOCUMENTATION AND RECORD KEEPING

Keys for effective documentation:

- Record everything!
- Details are important
- Clarity is important
- Drawing pictures or diagrams helps
- Photographs are incredibly useful
- Scan and upload notes ASAP



Subject: CONSTRUCTION OBSERVATION; D/S 13-2 PERM CASNG Date: 29 APRIL 2022

0820 Arrive on site.
Michels is drilling from barge for 13-2
Get ride out to barge from boat by Cage for 13-2, which appears to be nearly complete.
At depth of 48 ft below T/Temp Casing Material is brown
Bentonite is near top of Temp Casing
Top of Temp Casing is EL 572.1
Temp Casing is 45 ft long ∴ B/Temp Casing is EL 527.1 ft
Mudline is at 29 ft below T/Temp Casing = EL 543.1 ft
Embedment of Temp Casing = 16 ft
Permanent Casing is 75'8" long ... hanging from crane weight at 88'6" - 12'10" = 75'8"

0900 Stop for weather

1115 Resume drilling

1220 Hit rock at depth of 73 ft(±) ... corresponds to EL 499ft ... based on drill depth water not cleaned out; likely >73 ft.
Switch from drilling bucket to earth auger

1249 Stop for weather again

1500 Resume drilling

1545 Finish augering out sand and switch to core barrel

1615 Finish up core and switch to core barrel, cut 1 core

1631 Finish 1 core Sea reports core barrel was advanced about 1 ft, to 74 ft, but barge was bouncing

1640–1715 Set casing w/ crane.
Top perm is 35" above Temp before twisting

1720–1745 Twist in. Top Perm is 19" above Temp after twisting. Couldn't twist any more

1800 Leave site.

IMPORTANCE OF EFFECTIVE DOCUMENTATION

Source: www.prevention.com

WHAT'S DIFFERENT?

Keys for effective documentation:

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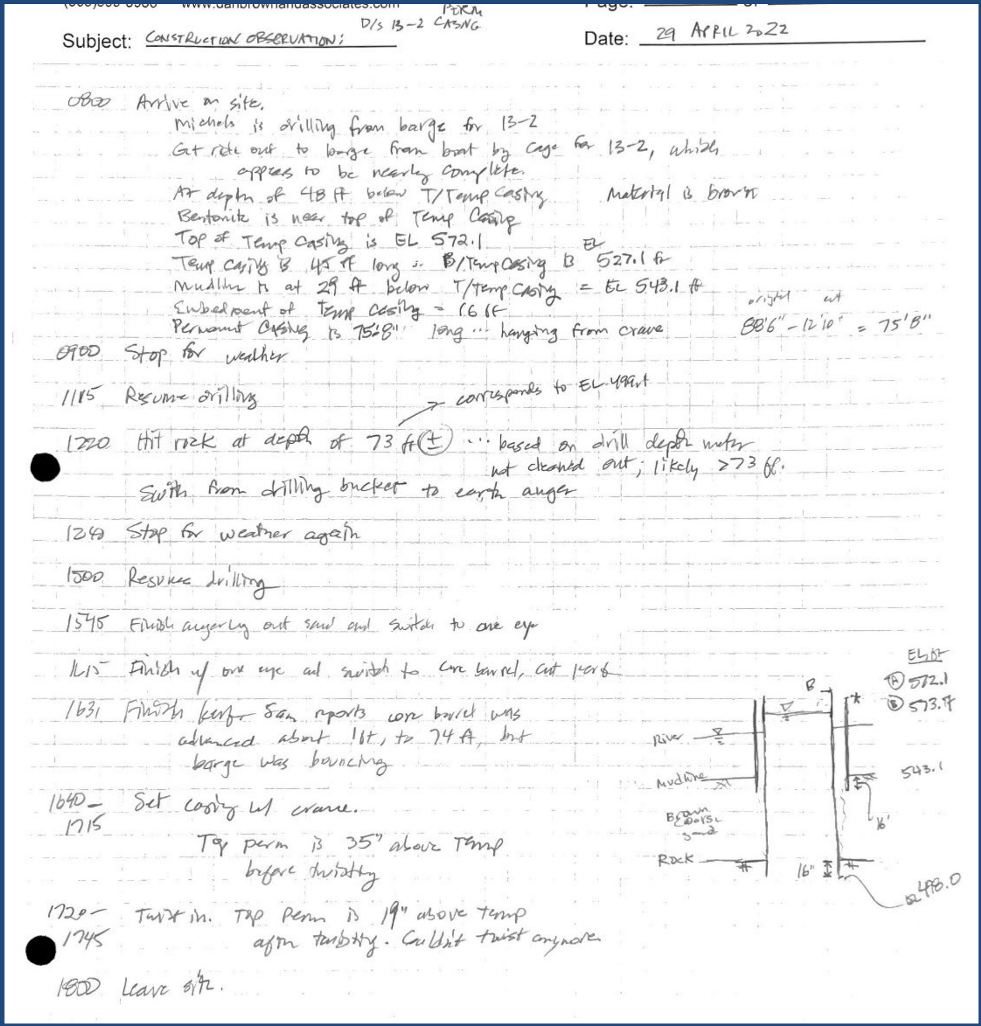

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Switch from drilling bucket to earth auger
1240 Stop for weather again
1500 Resume drilling
1545 Finish augering out sand and switch to one eye
1615 Finish up one eye and switch to core barrel, cut kerf
1631 Finish kerf. Sam reports core barrel was advanced about 1 ft, to 74 ft, but barge was bouncing
1640–1715 Set casing w/ crane.
Top perm is 35" above Temp before twisting
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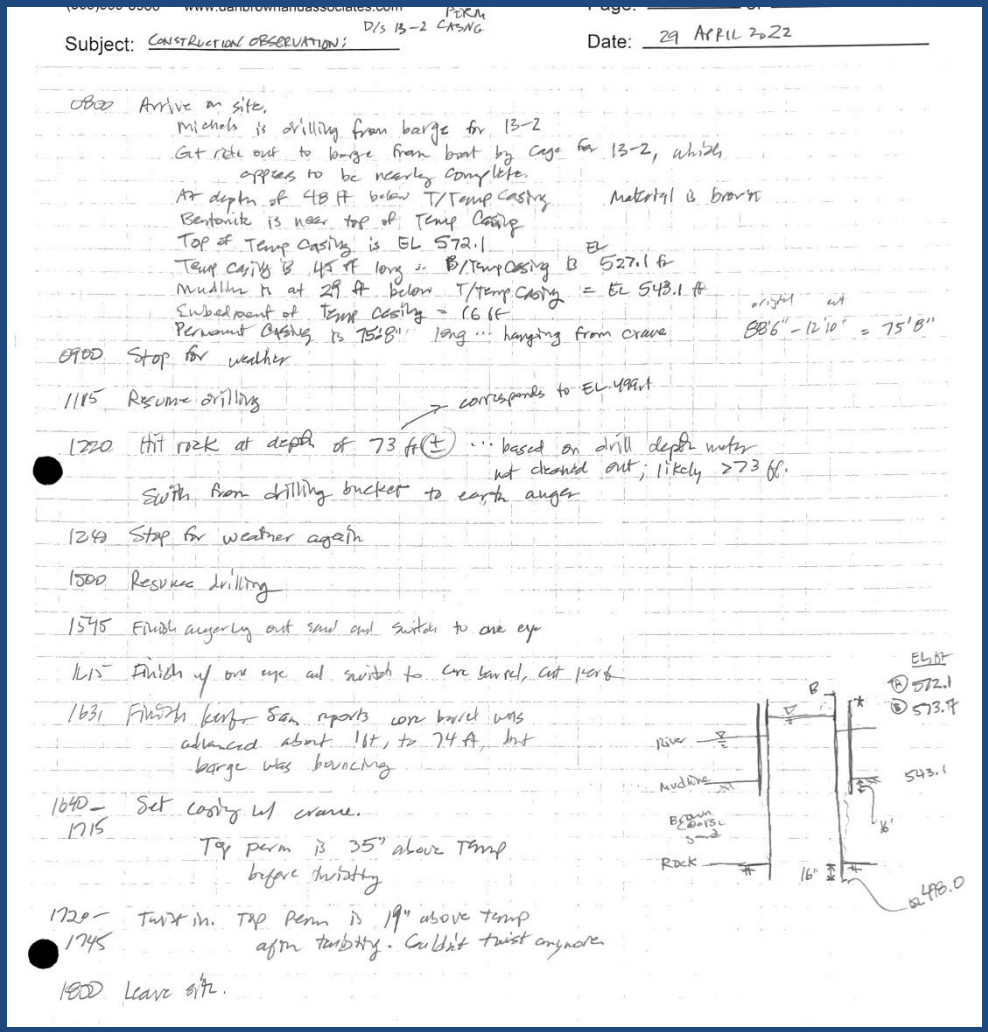

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INSPECTION OF FOUNDATION ELEMENT GEOMETRY AND LOCATION (CONSTRUCTION TOLERANCE)

- Inspection should ensure the foundation element is
  1. Installed in the proper location and at the proper inclination
  2. The right size
- Both (1) and (2)
  - Are evaluated versus the plan values and specification tolerances
  - Apply to any reinforcing steel included in the foundation element
- Inspection of geometry and location is not fundamentally different from inspection of same items for above-ground elements.

PERFORMANCE VERIFICATION

- Load testing is the most direct form of performance verification for deep foundation elements
- Demonstrates the ability of the constructed foundation to achieve the required performance
- Indicator of the effectiveness of the means and methods for constructing the foundation element
- Can be used to optimize design, construction procedures, and/or acceptance criteria
- Static load testing typically not used as a direct means for final acceptance

PERFORMANCE VERIFICATION

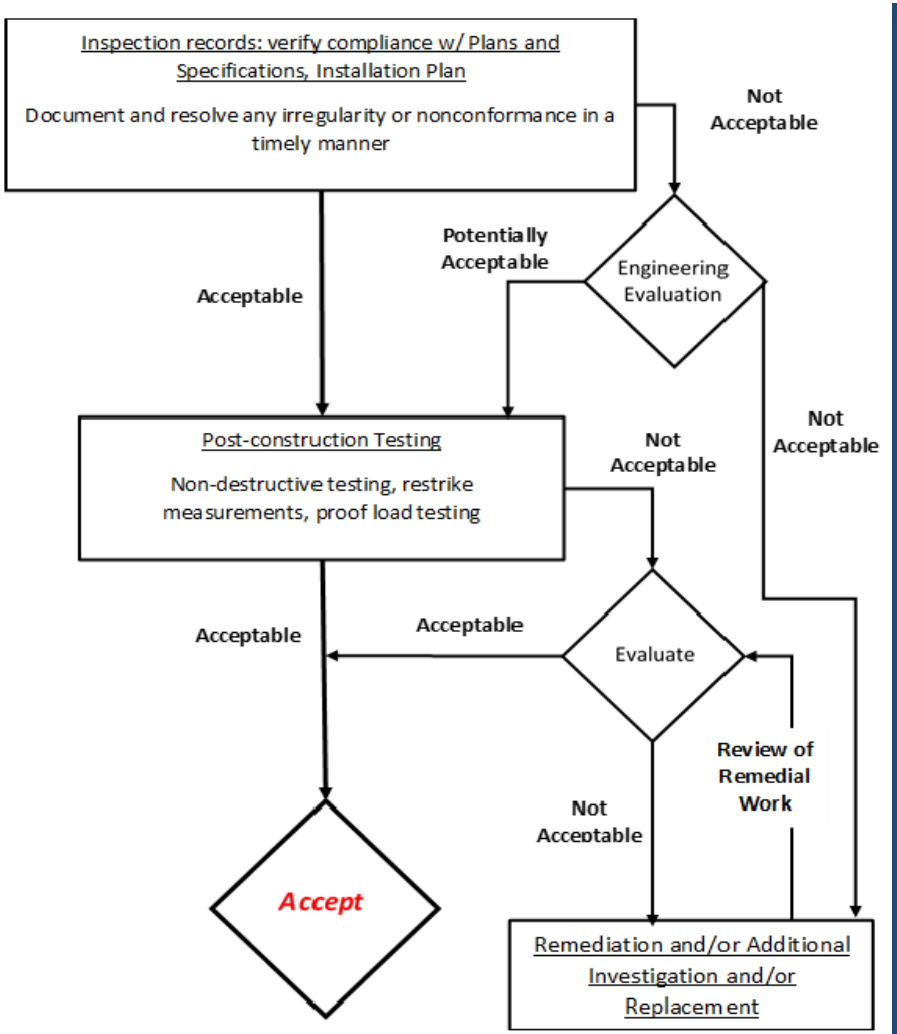
- Use analysis or testing to evaluate performance of a constructed foundation element
- Analysis is similar to design analysis, but with as-constructed parameters
- Load testing considerations:
  - Timing, i.e., design-stage vs. construction-stage
  - Frequency, i.e., number of elements to test
  - Target test load
  - Evaluation criterion, i.e., what is "failure"?

ELEMENT INTEGRITY

- Provides assurance that a constructed foundation element is sound and complete
- Methods are typically non-destructive and performed as post-construction evaluations
- Best suited for the assessment of foundation conditions that cannot be easily observed during construction
- Requirements vary by foundation type, agency, and project
- Should not be considered as a sole basis for acceptance of deep foundation elements

Contractor and Equipment Arrive on Site	YES	NO	N/A
1. Has the Contractor submitted a Drilled Shaft Installation Plan?			
2. Has the Drilled Shaft Installation Plan been approved?			
3. Does Contractor have an approved concrete mix design?			
4. Has Contractor run the required Trial Mix and slump loss test for the concrete mix design?			
5. If concrete placement is estimated to take over two hours, has Contractor performed a satisfactory slump loss test for the extended time period?			
6. If Contractor proposed a mineral or polymer slurry, do they have an approved Slurry Management Plan?			
7. Have you attended pre-construction conference with the Engineer and Contractor for clarification of drilled shaft installation procedures and requirements?			
8. Is Contractor prepared to take soil samples or rock cores on the bottom of the shaft, if required in the Contract Documents?			
9. Has the Contractor met the requirements for protection of existing structures?			
10. Has the site preparation been completed as specified?			
11. Does Contractor have all the equipment and tools shown in the Drilled Shaft Installation Plan?			
12. If casing is to be used, is it the right size?			
13. If Contractor plans to use a slurry, do they have the proper equipment to mix it?			
14. Is the manufacturer's representative on site at the start of slurry work?			
15. If a slurry de-sander is required, does Contractor have it on site and operational?			
16. Does Contractor's tremie meet the requirements of the Specifications?			
17. Do you have all the drilled shaft forms that are needed during shaft construction?			
Technique Shaft			
18. Is the technique shaft positioned at the approved location?			
19. Has Contractor installed the technique shaft as specified?			
20. Did Contractor cut off the shaft below grade as specified?			
21. Does Contractor have approval for revised procedures and equipment identified during technique shaft installation?			
Shaft Excavation and Cleaning			
22. Is the shaft being constructed in the correct location and within tolerances?			
23. Does Contractor have a benchmark for determination of the proper elevations?			
24. If core holes are required, has Contractor taken them in accordance with the Specifications?			
25. If a core hole was performed, was a Rock Core form completed and did Contractor maintain a log?			
26. If Contractor is using slurry, did they perform tests and report results in accordance with the Specifications?			
27. Is the slurry level being properly maintained at the specified level?			
28. Are the proper number and types of tests being performed on the slurry?			
29. Are you filling out the Drilled Shaft Excavation forms?			
30. If permanent casing is used, does it meet requirements of Contract Documents?			
31. If temporary casing is used, does it meet the requirements of the Specifications?			
32. Is the shaft within allowable vertical alignment tolerance?			
33. Is the shaft of proper depth?			
34. Does the shaft excavation time meet the specified time limit?			
35. If over-reaming is required, was it performed in accordance with Specifications?			
36. Does the shaft bottom condition meet the requirements of the Specification?			
Reinforcing Cage			
37. Is the rebar the correct sizes and configured in accordance with the project plans?			
38. Is the rebar properly tied in accordance with the Specifications?			
39. Does Contractor have proper spacers for the steel cage?			
40. Does Contractor have proper number and spacing of spacers for the steel cage?			
41. If steel cage was spliced, was it done in accordance with Contract Documents?			
42. Is the steel cage secured from settling and from floating?			
43. Is the top of the steel cage at proper elevation in accordance with specified tolerance?			
Concrete Placement			
44. Prior to concrete placement, has the slurry (both manufactured and natural) been tested in accordance with the Specifications?			
45. Was the tremie pipe within specified maximum height above the shaft base at the start of concrete placement?			
46. Was a flap valve or "pig" used to separate concrete from slurry at the start of concrete placement?			
47. Was the discharge end of the tremie maintained at the specified minimum embedment in the concrete			
48. If free-fall placement (dry shaft construction only), was concrete place in accordance with the Specifications?			
49. Did concrete placement occur within the specified time limit?			
50. Are you filling out the Concrete Placement and Volume forms?			
51. Did Contractor overflow the shaft until good concrete flowed at the top of shaft?			
52. If required, was the casing removed in accordance with the Specifications?			
53. Were concrete acceptance tests performed as required?			
Post Installation			
54. Is all casing removed to the proper elevation in accordance with Specifications?			
55. If required, has Contractor complied with requirements for Integrity Testing?			
56. Is the shaft within the applicable construction tolerances?			
57. Have all Drilled Shaft inspection forms been completed?			
58. Have you documented the pay items?			
Notes/Comments:			

FRAMEWORK FOR EVALUATION AND ACCEPTANCE



REMEDIATION OF DEEP FOUNDATIONS

- Remediation work requires plan with involvement of engineer and potentially new information and analysis.
- General strategies:
    1. Repair
    2. Retrofit
    3. Replace
- Remediation requires acceptance, too.

FHWA GOALS FOR FRAMEWORK

- A rational approach for integrating available QA and QC tools for making deep foundations acceptance and payment decisions
- Promote equity in acceptance procedures for different deep foundation types
- Generic and flexible framework reduces issues with the reliability of deep foundation elements as a function of construction control

CONSEQUENCES OF POOR ACCEPTANCE PROCEDURES

Poor inspections, lack of documents, or poor testing:

- Errors or irregularities are missed
- Unable to verify compliance
- Hinder or delay acceptance
- Hinder or delay accepting remediation
- Impede claim resolution

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THANK YOU!

Silas C. Nichols, P.E.
Principal Geotechnical Engineer
Federal Highway Administration
Office of Bridges and Structures

Phone: 202-366-1554
Email: Silas.Nichols@dot.gov

Website:
fhwa.dot.gov/engineering/geotech